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Production of activated carbon nanofibers from the recycling of worn tire tires

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Abstract

Tire recycling or tire recycling is a process in which car tires are no longer worn out or are no longer suitable for use because of a rupture or unrepairable failure. These tires are among the most significant waste that is very problematic. This problem is due to the persistence and persistence of tires and their high volume of production. It is estimated that 259 million tires are discarded each year. In this research, the Preparation stages of production of activated carbon nanofibers produced from the recycling of worn tire rubber with different percentages of different solvents of potassium hydroxide, ethanol, and toluene were studied and tested. To achieve a solution for worn tire tires, a certain amount of scraped rubber fragments was dissolved in potassium hydroxide, ethanol, and toluene solvents, and electrospinning solutions were determined and prepared and to produce nanofiber layers, Electrospinning operations are performed. By scanning electron microscopy images, the mean diameter of nanofibers obtained in potassium hydroxide solvent was the lowest, and scanning electron microscopy images confirmed the absence of willow in the produced nanofibers. The efficiency of carbon production was determined as 37.2%. To confirm the formation of activated carbon, FTIR spectra were used, which confirmed the presence of spike related to the aromatic ring formation of activated carbon nanofibers after activation.

Keywords

Recycling, Environment, worn tires, Electrospinning, activated carbon, Carbon fiber.

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Introduction

The environment is one of the many blessings God has given us and we need it to continue. The reason for increasing attention to the environment can be its importance in supplying raw materials and its tremendous impact on the nature of human life. In earlier times, because the human population was not abundant, they needed fewer resources, and resource use and exploitation were scarce, so humans did not have much impact on their surroundings and there was no concern about environmental problems. But with the explosion and the increase in population, the need for human resources became more and more and more. The exploitation of resources was determined due to the high population growth and the destructive effects of these exploits on the environment, and concerns about this issue increased. In other words, the advancement of human technology in the last two centuries has dramatically increased the power of human influence on the environment and caused the dimensions of environmental problems caused by human activities to gradually expand from local, national, regional, and ultimately global levels [1].

Therefore, today, the environment and its preservation as well as attention to environmental issues is one of the important issues that is of interest to the world and its impact on human life is undeniable. Today, the ability to recycle resources is of great importance. Recycling prevents further damage to the environment because it makes used resources reusable and prevents the overuse of new resources. In general, recycling is the process of reusing waste materials and converting them into new sources and materials for use. Also, recycling is used for proper and efficient waste disposal and for reducing environmental pollution. The practice of recycling by helping to reduce the use of new resources and reduce pollution serves to improve and sustain the economy. Recyclable materials include all kinds of glass, paper and cardboard, fabric, metal, electronic and rubber materials. At the recycling center the collection of recycled materials, these resources are sorted and after cleaning are converted back into usable materials and are put into the production cycle. Rubber recycling in industrialized countries has a long history. During World War II, the United States purchased many natural tires from other countries. And at the same time, most of the worn tires were recycled, and tire recycling flourished in rubber factories [2]. Tire manufacturing plants, aware of the characteristics of the rubber, achieved the production of elastomer through high heat. This point marked the beginning of more use of worn tires for all manufacturers. Operations on worn tires were mainly done through energy-efficient methods of recovery, such as use as waste fuels in power plants, cement kilns, or by recycling materials themselves, such as the use of rubber-derived crumbs for flooring, asphalt, building materials, sports grounds, roof coverings [3,4].

Recycling worn tires does not harm the environment and makes it possible to produce other products, as well as economically and industrially, growth and profitability. Most polymer waste in the world is worn tires, which due to the ingredients, structure and materials added for decomposition are facing serious problems. Rubber is a material that has elastic properties. The properties of rubber include increased length, low elasticity, and high rate of contraction. The increasing number of vehicles in the last few decades has caused a rapid increase in tire waste. If this volume of rubber is not properly recycled, it will become a home for insects and animals. Also, because the construction of tires uses chemicals that are not degradable in the environment, and if they are buried, they transfer toxic substances to the ground and cause ground pollution and groundwater pollution, recycling of worn tires is of great importance [6]. To this end, the effective use and management of worn tires is based on the size, quality, and shape of the product being used and can have many applications, including the production of activated carbon.

In recent years, activated carbon has been studied as one of the materials that can be used in the water and wastewater industry. The removal of many pollutants from liquid and gas environments using activated carbon has been successfully carried out, while other methods such as coagulation and flocculation for water treatment are not suitable and during these processes, it is possible to produce waste. But while the use of ion exchange technology as well as the technology used in membrane filters has been successful, the disadvantages of these technologies include difficulty in operation as well as their high cost. However, the technology to produce activated carbon from worn tires does not have these disadvantages [7].

Due to the reasons and problems mentioned above, the main purpose of this research is to recycle tire rubber and prevent environmental problems caused by the presence and accumulation of rubber in nature and the environment, which recycling rubber prevents damage to the environment as well as humans and animals and irreparable damages. Another goal of the research is the effective use of recycled tires and the production of activated carbon from them, which have many benefits in the fields of industrial, water and wastewater, etc... He has.

Activated carbons due to their properties and low price compared to other inorganic materials such as zeolite are considered as one of the most important elements in the industry [8]. Activated carbon refers to amorphous carbon-bearing materials that differ from the current definition of crystalline nanoparticles that have a special surface area and high porosity and have an irregular structure than graphite [9]. There are different types of specific surface areas in activated carbon, ranging from 250 to 2500 m (about 1.55 mi) ^2 (about the area of a large mansion)/g, and even activated carbons with a specific surface area above this amount can be produced for specific applications that require a high specific level. The adsorbent ability of activated carbons can be used to separate different materials from each other and purify them [10]. In recent years, waste tires have accounted for a large share of the precursor to the production of activated carbon, due to the production of more than 250,000 tons of waste tires per year in Iran and the high ability to use the existing capacity of waste tires, it can be planned to use this capacity. Currently, the amount of waste tires with recycling capacity of about 54,480 tons and worn tire the depot is 200015 tons (6.78). Also, the low price of waste materials such as worn tires can provide a lot of cheap and renewable resources to produce activated carbon. It can be described as one of the most valuable sources of activated carbon production. High active carbon production (25% mass) as well as very low volatile ash (5% >) of waste tires are advantages of waste tires [11, 12].

The production of activated carbon is carried out in two phases of carbonization and activation, which can be done simultaneously or separately, which we will discuss in the following two steps.

Sun et al. investigated the production of activated carbon from coal called bitumen, a state coal in the United States, and rubber in 1997, using water vapor and carbon dioxide for the physical process, and for the chemical process they used activated substances such as zinc chloride, potassium carbon, and phosphoric acid. Various experiments were carried out on activated carbon such as microporous volume measurement, cavity size distribution, nitrogen adsorption and mass density.

The results of these experiments for two forms of carbon that were pellet and granular carbon were that the carbons on which the coal pre-oxidation was carried out had more micropores than those on which the carbon had not been conducted. Activated carbon produced from rubber has more desaturation and microcavity than activated carbon produced from coal [13].

In 2001, Hu and colleagues in Singapore conducted a study to obtain microporous and high-mesoporous activated carbon. Researchers prepared activated carbon by chemical method under zinc chloride using precursors such as palm seeds and coconut peel. Also, thermal nitrogen adsorption test was performed on activated carbon under 77°C. 2400 m (about 1.49 mi) ^2 (about four times the area of a basketball court)/g for BET levels of more carbon. Also, 94% of the carbon from palm grains was mesoporous TGA test was used to determine the quality and quantity of carbon produced from coconut skin pyrolysis. Useful items in this research can be summarized as inexpensive and cost-effective precursors, a stage of activation of suitable distribution of cavity sizes, large cavity volumes and special active surface [14].

In 2004, Largie et al. carried out the pyrolysis process of rubber hubs in the presence of nitrogen gas at various temperatures (including 300, 400, 500, 600, 700 °C). During this process, a temperature of 500 °C was considered the optimum temperature, at which the temperature of the product was obtained in liquid form of 38% wt. Also, observations showed an increase in the production of liquid from 300 °C to higher temperatures, the highest value of which was 38% wt., and occurred at 500 °C. Hydrolysis process was evaluated by different parameters until it reached ambient temperature. For example, the gross thermal value of this production product was measured as 42 megajoules per kilogram, which was compared to diesel fuel, and in this comparison, it was found to have a good gross thermal value [15].

In 2017, Alvarez et al. looked at the pyrolysis of worn tires from a tractor at a temperature range of 425 to 575 °C, and they used a conical reactor for this process. In this research, it was found that with increasing temperature, we have a decrease in liquid production, but gases that cannot condensate increase. They then distilled the produced liquid and compared the resulting distillation curve to gasoline and gasoline, which ultimately concluded that although the liquid produced is good, the liquid produced does not have volatility and its hydrocarbon distribution does not resemble those of the other two fuels, so it cannot be used directly as a substitute [16].

Research Background

In 1992, Barlas and colleagues explored the possibility of using worn tires as sources of energy and the possibility of using them on road pavements. The study was conducted in North Carolina. According to reports, worn tires can be used as fuel and alternative energy sources in cement and paper mills[5].

In 2008, Frevo and colleagues in Portugal adopted a system for managing worn tires in Portugal, in which the decision of the Portuguese government adopted the EPR Manufacturer's Liability Development System to manage worn tires, during which manufacturers had to use a management system to collect waste for recycling and reusing ELT. In this system, recyclers, manufacturers, distributors and veneers were identified, as well as the need to investigate the infrastructure for local processing. The information obtained in this system was used to design and prepare an economic management system [17].

In 2010, Li and colleagues compared existing management technologies in China economically and environmentally. Existing technologies including crushing, devulcanization, pyrolysis and extraction were evaluated. The results showed that the most appropriate method and technology is pyrolysis and extraction do the worst damage. For the other three methods, high reliability was demonstrated when the avoidable effects of recycling materials and energy were considered, often resulting from energy production. In 2001, 75 million tires were produced in China, representing 150 million in 2006. The five main methods of disposal in China include coating, crushing, devulcanization, pyrolysis and extraction [18].

In 2015, Torta and colleagues looked at how worn tires were processed and disposed of in Italy and Romania. This study investigates the characteristics of worn tires, the possibility of recovery and its various methods, quality improvement. Other aspects of it are also considered related to energy recovery as well as the application of life cycle analysis as a back-up of management system. In Italy, illegal management of tires is fought, and part of tires are exported for reuse. Tyre coatings have increased due to the economic crisis. In 2011, 60,000 tons of ELT were collected in Romania, which was recycled at 20% and reused at 5%. In comparison between the two countries‹ the main differences in economic fields are:

- Italian customers tend to laminate tires due to the mentioned economic factors.

- In Romania there are many problems in reusing and coating tires.

- The existence of civil applications in Italy and the absence of this application in Romania

- Italy's good recycling trend and preference for lower cost investment in Romania

- Energy recovery in Romania through cement factories [19].

Ahmadpour and Doe obtained activated carbon from Australian coal in 1996, both physically and chemically. For physical activation, carbon dioxide and potassium and zinc chloride were used for chemical activation. To optimize the parameters affecting carbonization, these parameters including time, particle size, mixing method, temperature and chemical factors were investigated.

Anguished et al. (2007) [20] and Iota Mono et al. (2006) [21] independently found results including the efficiency of activated carbon produced in their use in the removal of petroleum compounds in aqueous environments. In 2007, Hashemi Nejad [22] and colleagues were able to use contaminated gasoline to purify water.

In 2010, Mendelian and colleagues investigated the production of activated carbon. In this study, he produced activated carbon from coal produced from pyrolysis bicarbonate and chemical and physical methods. Bicarbonate pyrolysis was carried out at 900 °C for one hour at 5 °C/min. Physical activation was performed at at atmospheric pressure at 950 °C. This section took place in different stay times of one, four and eight hours. Chemical activation was also carried out under several different conditions. These conditions included the temperature range of 800-600 °C and the use of potash in ratios of 1.6, 1.4 and 1.

The results of these experiments, which investigated the carbon properties by adsorption of carbon dioxide and nitrogen and by mercury coroscopy, show that the type of cavities is micro in the activation by potassium and in the activation by carbon dioxide in the form of meson. Also, the study of hydrogen and methane storage capacity showed that microporous structure of hydrogen and methane uptake increases hydrogen uptake. This study was conducted in a high-pressure adsorption system [23].

Research Method

In this section, the specifications and details of the materials used in the tests as well as the necessary devices, performed tests, test methods and evaluations are presented.

Consumables Specifications

The consumables used in the test are introduced below:

1. Tire shards with sizes of 0.088-0.125 mm (about 0 in) according to ASTM C33 prepared from Yazd Tire Factory

2. Potassium hydroxide prepared from Sigma Aldrich company

3. Ethanol made from Sigma Aldrich company

4. Toluene with purity of 5.99 prepared by Sigma Aldrich Company

5. Almond skin activated carbon from Pars Rafsanjani Co.

Used Devices

1. Shimadzu Libro AEU-210 scale, with an accuracy of 0.0001 g Japanese product available at Amir Kabir University Chemical Engineering Department

2. Magnetic stirred heater ARE model VELP with maximum 1000 rpm made in Iran available at Amir Kabir University

3. Electrospinning device available in Nano Laboratory of Textile Faculty Amir Kabir University of Technology

4. Converters with 220 V (AC) input and 0 to 30 kV output (DC) made in Iran available in Nano Laboratory of Textile Faculty of Amir Kabir University of Technology

5. TERUMO Feed Pump STC-527, 0 to 60 ml (about 2.03 oz)/h Product from Japan Available in Nano Laboratory of Textile Faculty of Amir Kabir University of Technology

6. Vacuum oven made by Mummert Company in Germany in Nano Lab of Textile Faculty Amir Kabir University of Technology

7. MB-series 100 Fourier transform infrared spectrometer (FTIR) made by Hartman & Braun Company, Canada, available at Amir Kabir University Chemical Engineering Department

8. Scanning electron microscopy (SEM) model VEGAII made by TESCAN Company in Czech country available at Amir Kabir University

9. Optical Microscope Available in Textile Engineering Department of Amir Kabir University of Technology

10. Laboratory furnace model KSL-1100X-S-H made by MTI corporation available at the Institute

11. Notes UV Digester Model 705 made by Metrohome Company available at the Institute of Materials and Energy

12. The Fourth Amendment Belkorp mini II for surface analysis of Bel company made in Japan available in Materials and Energy Research Center

13. The Martyrdom Incubator manufactured by Fan Armagost Co. available at the Institute of Materials and Energy.

Software used

1. Microsoft Office Word 2016 under Windows 10

2. Microsoft Office Excel 2016 under Windows 10

3. Digipeater software.

Dissolving Tire

Solutions to be prepared include:

- Tires with 5, 10, 15 and 20 percent by weight of potassium hydroxide (compared to tire tires)
- Tires with 5, 10, 15 and 20% by weight of ethanol (compared to tire tires)
- Tires with 5, 10, 15 and 20 weight percentages of toluene (compared to tire tires)

These solutions were stirred continuously at ambient temperature for 23 hours by a magnetic stirrer with constant shear rate and then subjected to ultrasonic device twice for 30 minutes.

According to the results obtained from dissolving rubber prepared with potassium hydroxide solvent, it was found that better results for dissolving rubber occur in 10, 15 and 20 wt.% potassium hydroxides, but in this experiment, the solution of rubber in 5% by weight of potassium hydroxide was not achieved.

Also, the results of dissolving the rubber prepared with ethanol solution showed that the only percentage that can dissolve the rubber is 20% by weight of ethanol, which was not fully dissolved in this solvent.

The results of this experiment to dissolve rubber in toluene solution determined that the best solubility occurs in a solution of 15, 10 and 20 percent by weight.

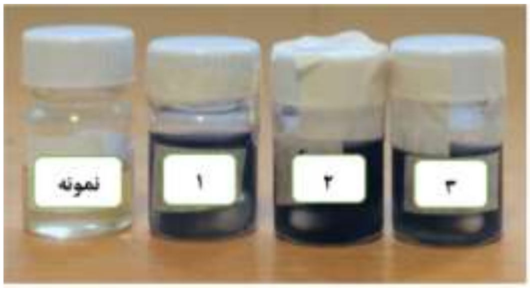
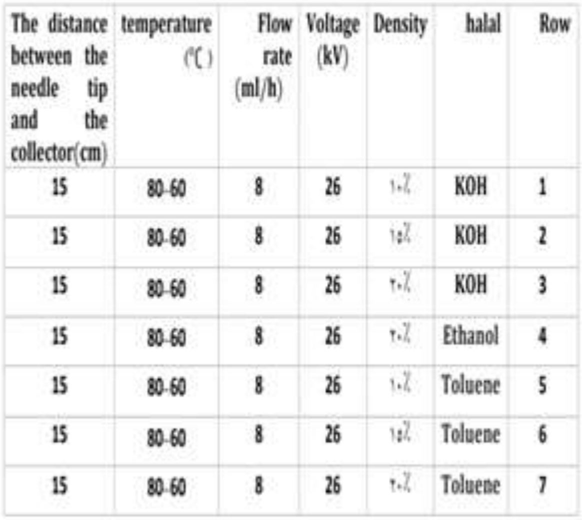


Figure 1: Sample of Prepared Solutions

Electrospinning Solutions

Electrospinning of the solutions was performed at approximate temperature at the Faculty of Textile of Amir Kabir University of Technology immediately after the preparation of the spinning solution. The pre-prepared solution was removed by syringe. The syringe containing the solution was placed in a special place on the pump. The distance between needle tip and collector was adjusted and the desired rate of solution feeding was applied. Then, the positive pole of the current source was connected to the needle tip and negative pole to the collector coated with aluminum coating, and then the desired voltage was applied to create spinning jets and form and collect nanofibers. The electrospinning conditions of spinning solutions are shown in Table 1.

Table 1: Electrospinning Conditions of Spinning Solutions



The distance between the needle tip and the collector(cm)	temperature (°C)	Flow rate (ml/h)	Voltage (kV)	Density	halal	Row
15	80-60	8	26	۱۰٪	KOH	1
15	80-60	8	26	۱۵٪	KOH	2
15	80-60	8	26	۲۰٪	KOH	3
15	80-60	8	26	۲۰٪	Ethanol	4
15	80-60	8	26	۱۰٪	Toluene	5
15	80-60	8	26	۱۵٪	Toluene	6
15	80-60	8	26	۲۰٪	Toluene	7

Measurement of weight changes of activated carbon nanofibers

After carbonization, the weight of nanofibers produced from worn tires decreases due to the ejection of non-carbon elements. This weight loss can be calculated from relation 1:

(1) $m= (1- m_c/m_p) \times 100$

In this regard, m% weight reduction, mc mass of activated carbon nanofibers and mp mass of nanofibers produced from worn tires.

In summary, the stages of the research will be as follows:

Steps of research:

For the preparation of nanofiber layers، the following steps were taken:

1) Electrospinning solution

2) Electrospinning and production of nanofiber layers

3) Placement of nanofiber layers in furnace for production of activated carbon nanofibers

Analysis of Results:

The main objective of this study was to construct and characterize activated carbon powder from recycling of worn tires. In this section, after determining the appropriate conditions of nanofibers electrospinning, first we investigate the possibility of electrospinning solutions obtained from the solution of worn tires, and then morphology and the diagonal changes of the mean diameter of electro spun nanofibers are investigated.

Nanofiber Electrospinning

The injector syringe containing 1 ml (about 0.03 oz) of electrospinning solution was placed on the pump (with the ability to pump in the range of 0 to 200 ml (about 6.76 oz)/h). The soluble feed rate was adjusted to the desired amount. Aluminum foil that was placed at a good distance from the tip of the needle was used as a collector on drum. The electrospinning device used is shown in Figure 4-1.

Figure 2: The electrospinning device used

determination Conditions electrospinning solutions Prepared

To investigate the effect of polymer concentration and its various solvents on the morphology of electro spun nanofibers, it was tried that the conditions of electrospinning which include spinner-collector distance, electrospinning solution feeding rate and applied voltage for all polymer solutions to be the same and nanofibers should be produced uniformly and without any willow under the same conditions. After initial investigations, the possibility of achieving these conditions was realized.

In this project, the voltage is 26 kV, the power rate is 0.08-0.09 ml (about 0 oz) ⁄(h), and the spinner-collector distance is 15 cm (about 5.91 in). Also, all electrospinning was done at ambient temperature and relative humidity of 29%. Preliminary investigation of morphology of electro spun nanofibers by optical microscope To initial study of nanofibers and to achieve the proper conditions of electrospinning and to study the nanofibers produced in terms of producing uniform diameter fibers without any defects and grains, a thin layer of nanofibers was collected on a clean and transparent laminar surface and was observed by optical microscopy with magnification of 1000. After examining the intuitive signs that continuous and uniform exit of the solution jet without any dropping, electrospinning conditions were approved. In this research, we try to control the parameters affecting electrospinning such as solution viscosity, applied voltage, power rate and needle distance to collector plate to allow continuous and low diameter fibers and uniform distribution.

Effect of Concentration Changes of Polymer and Nano Particles on Morphology of Electro spun Nanofibers To study the morphology of electro spun nanofibers, images taken by scanning electron microscopy at the Iranian Institute of Materials and Energy were used. These images were randomly obtained from different areas of the nanofiber layer collected on aluminum foil. Under these conditions, the effect of different concentrations and solvents on the morphology of electro spun nanofibers was investigated.

Figures 3 to 9 show scanning electron microscopy images of nanofibrous membranes prepared from worn tires with different concentrations of rubbers and solvents with magnification of 10000. Mean and standard deviation values were determined by Dig Meiser software and reported in Table 1.

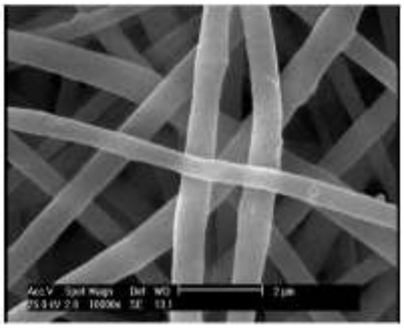


Figure 3: Scanning electron microscopy image for nano-fibrous membranes with 10 wt% potassium hydroxide solvent

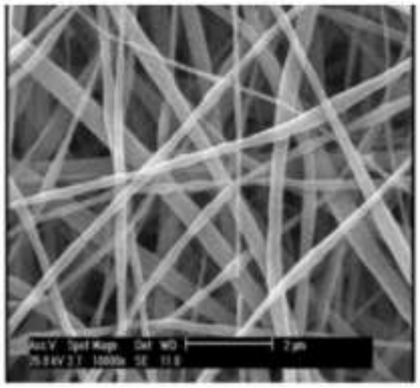


Figure 4: Scanning electron microscopy image for nano-fibrous membranes with 15% by weight of potassium hydroxide

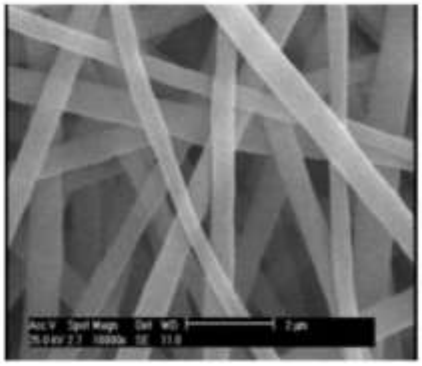


Figure 5: Scanning electron microscopy image for nano-fibrous membranes with 20% potassium hydroxide solvent

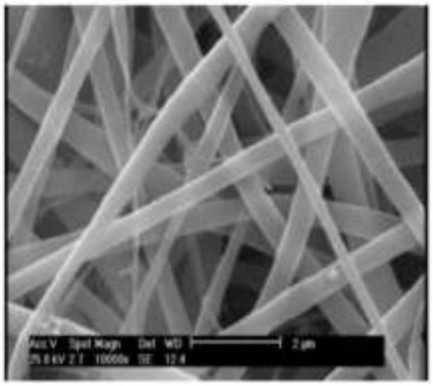


Figure 6: Scanning electron microscopy image for nanofiber membranes with 20% ethanol by weight

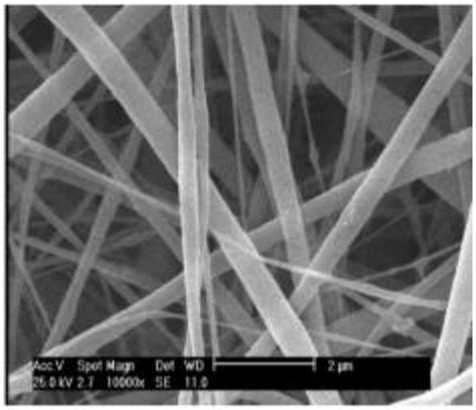


Figure 7: Scanning electron microscopy image for nanofiber membranes with 10% toluene by weight

Figure 8: Scanning electron microscopy image for nano-fibrous membranes with 15% toluene by weight

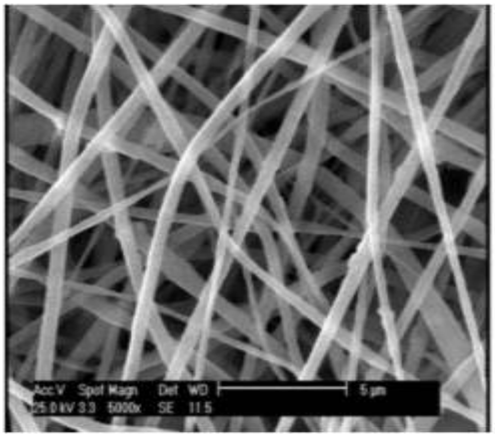


Figure 9: Scanning electron microscopy image for nano-fibrous membranes with 15% toluene by weight

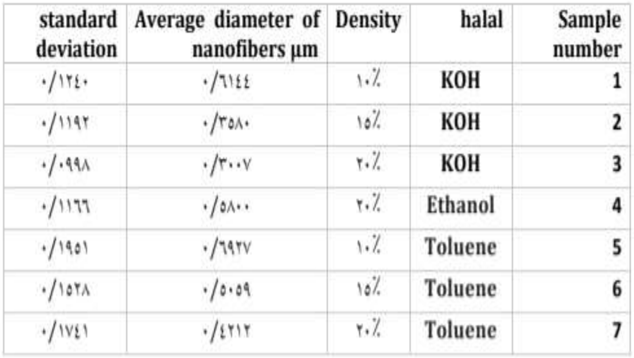
According to the images that scanning electron microscopy shows, the resulting nanofibers are without any defects or grains. The images also show that the resulting nanofiber membranes consist of many nanofiber layers, with many pores in each layer between the fibers.

To investigate the effect of polymer solution concentration in this study and the use of different solvents on morphology of nanofibers, polymer solutions with different concentrations and solvents were prepared. For dilute polymer concentrations with less than weight in all the solvents, only polymer droplets were formed. The concentration of 10% wt% for ethanol solvent was not spinning and with a concentration of 15% by weight this solvent was formed.

Also, nanofibers with uniform structure were obtained in polymer concentration between weight percentage for potassium hydroxide and toluene. Finally, at a higher concentration of weight, ribbon fibers were formed. As can be seen from Figure 3 and Table 1, which show the average diagonal mean of nanofibers, the mean diameter of nanofibers has decreased in the presence of a high percentage of potassium hydroxide solvent, which could be due to reduction in the viscosity of the solution that Jiang and Guan have confirmed an increase in the diameter of nanofibers by increasing the solution viscosity[24,25].

It was previously pointed out that in the electrospinning method, many parameters including process, solution and environmental parameters such as humidity and ambient temperature affect the morphology and diameter of the resulting nanofibers. As mentioned before، it is tried to be the same process parameters including the spinner-collector distance، the feeding rate of the electrospinning solution and the applied voltage at all stages of the nanofiber membrane production. Therefore, only the concentration of polymer solution and different solvents is investigated here.

Table 9: Average Diagonal and Standard Deviation of Nanofibers Produced from Worn Elastics



standard deviation	Average diameter of nanofibers µm	Density	halal	Sample number
٠/١٢٤٠	٠/٦١٤٤	١٠٪	**KOH**	**1**
٠/١١٩٢	٠/٣٥٨٠	١٥٪	**KOH**	**2**
٠/٠٩٩٨	٠/٣٠٠٧	٢٠٪	**KOH**	**3**
٠/١١٦٦	٠/٥٨٠٠	٢٠٪	**Ethanol**	**4**
٠/١٩٥١	٠/٦٩٢٧	١٠٪	**Toluene**	**5**
٠/١٥٢٨	٠/٥٠٥٩	١٥٪	**Toluene**	**6**
٠/١٧٤١	٠/٤٢١٢	٢٠٪	**Toluene**	**7**

With this explanation، and according to Table 2، which shows the diameter average of nanofibers and also by observing Figure 10، it can be said that increasing the diameter of nanofibers by reducing the concentration of polymer solution can be due to reduction of solution viscosity، and reducing the use of potassium hydroxide solvent reduces the diameter of nanofibers، which is very desirable because the diameter is less، It brings more specific contact points and surface area, which can be attributed to the high penetration of potassium hydroxide between polymer chains and the way these polymer chains move and interact together.

Also, as mentioned above, if the solution has a high electrical conductivity coefficient, in the first stage at lower voltage the accelerating current is formed, and in the next stage, due to the high conductivity of the solution, more force is applied to the solution and the accelerated current is stretched and curved and the diameter of the fibers decreases. It seems that this is the case with Toluene [26].

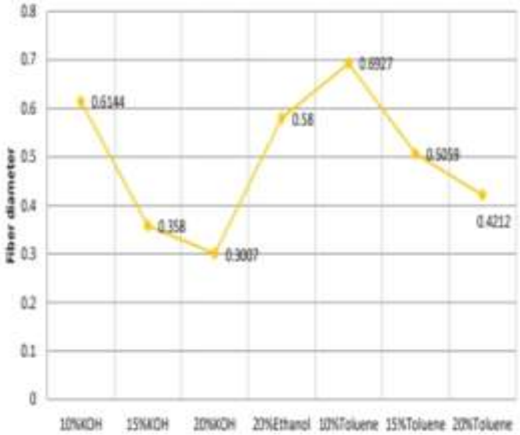


Figure 10: Diagonal changes of nanofibers in the presence of different solvents

Diameter Changes of Nanofibers in the Presence of Different ModesProduction of activated carbon nanofibers from prematernal of nanofibers

To produce activated carbon nanofibers, the nanofibers were scaled in the sample holding chamber of the tube furnace available at the Iran Institute of Materials and Energy and after writing the temperature-time program in the computer connected to the furnace, the device was turned on and the program was activated. Temperature-time diagram of the stabilization, carbonization and activation processes (temperature intervals of all three stages have been achieved by trial and error) is seen below. In the stabilization stage, the furnace temperature was initially raised at a slope of 2°C per minute at room temperature to 260°C and continuous heating continued for 1 hour at 260°C for 1 hour.

Then, in the carbonization phase, by injecting argon gas into the furnace chamber and increasing the temperature up to 600 °C with a slope of 2°C per minute, the heating continues again for 2 hours at 600°C. In the next step, the activation process is done by increasing the temperature to 800 °C with a slope of 4°C per minute and heating at this temperature for 1 hour. Finally, activated carbon nanofibers were removed from the furnace after the temperature dropped below 50°C.

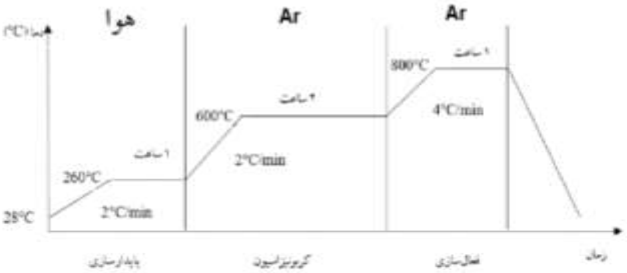


Figure 11: Thermo-time graph of the processes of stabilization, carbonization and activation of nanofibers

Then، after the operation described above، carbon nanofibers are obtained. Activated carbon can be prepared and examined in powder, extruded and fibrous forms and then the characterization of nanofibers and activated carbon fibers produced from them is investigated by different analyses.

Weight changes of carbon nanofibers produced

The weight loss of activated carbon nanofiber samples after carbonization (according to the weight of the sample) was determined based on

relation 1. Table 3 shows the data on this weight loss.

Table 3: Weight Changes in Samples of Carbon Nanofibers Produced

Weight loss of nanofibers (٪)	Weight of nanofibers after carbonization (grams)	Weight of nanofibers before carbonization (grams)	Weight concentration	halal	Sample number
٣١	٠/٢٥	٠/٣٦	١٠٪	**KOH**	١
٤٤	٠/١٦	٠/٢٩	١٥٪	**KOH**	٢
٤٥	٠/٠٦	٠/١١	٢٠٪	**KOH**	٣
٣٥	٠/١٣	٠/٢٠	٢٠٪	**Ethanol**	٤
٢٧	٠/١٩	٠/٢٦	١٠٪	**Toluene**	٥
٤٠	٠/٣٠	٠/٥٠	١٥٪	**Toluene**	٦
٤١	٠/١٠	٠/١٧	٢٠٪	**Toluene**	٧

According to Table 3, it is observed that by reducing the diameter of fibers, weight loss also increases. Also, by comparing the weight loss of nanofibers produced from 20% by weight of potassium hydroxide with 6 other nanofibers produced, it can be concluded that these nanofibers experience a greater weight loss.

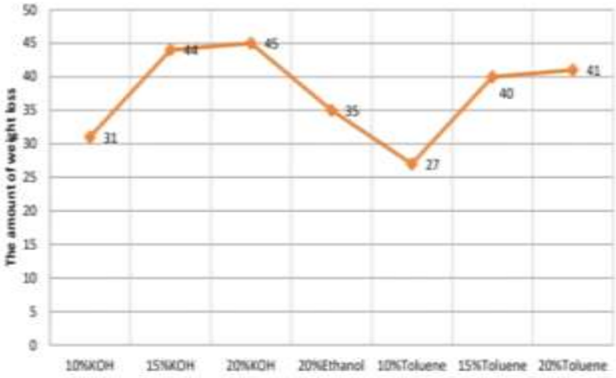


Figure 12: Percentage of weight loss in the presence of different solvents

Therefore, in the carbonization and activation processes, more non-carbon elements have been removed from this nanofiber, indicating an increase in carbon load.

Conclusion

In this study, the preparation of activated carbon from recycling of worn tires with different percentages of different solvents of potassium hydroxide, ethanol and toluene was investigated. The stages of the research and the results obtained from each stage are described below:

1. In the first stage, a certain number of fragmented parts of worn rubber was dissolved in potassium hydroxide solvents, to achieve solution of worn tire tires, ethanol and toluene and solutions with electrospinning capability were determined and prepared.

2. To produce nanofibers layers، electrospinning operations were carried out which during the electrospinning process parameters including the distance between spinners and collector and applied voltage in all stages of nanofibers production are considered similar. Therefore, in this study, only the effect of adding different solvents and their percentages was investigated. Optical microscopy images confirmed the granularity of the resulting nanofibers.

3. By observing scanning electron microscopy images, the lowest mean diameter of nanofibers obtained in the solution of potassium hydroxide has occurred, and scanning electron microscopy images emphasize the absence of willow in the nanofibers produced.

4. The amount of yield of activated carbon was determined and the highest production rate was 37.2%.

5. FTIR spectra was used to confirm the formation of activated carbon which is evidence of the presence of spikes related to aromatic ring formation of activated carbon nanofibers after activation.

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